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REPORT ON THE FOURTH UNITED NATIONS TRAINING COURSE ON REMOTE SENSING EDUCATION FOR EDUCATORS, HELD IN COOPERATION WITH THE GOVERNMENT OF SWEDEN

(Stockholm and Kiruna, Sweden, 2 May-10 June 1994)

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INTRODUCTION

A. Background and objectives

1. At its thirty-seventh session, the General Assembly adopted resolution 37/90 of 10 December 1982, in which it endorsed the recommendation of the Second United Nations Conference on the Exploration and Peaceful Uses of Outer Space (UNISPACE 82) that the United Nations Programme on Space Applications should promote the growth of indigenous nuclei and an autonomous technological base in space technology in developing countries.

2. The Committee on the Peaceful Uses of Outer Space, at its thirty-sixth session in June 1993, endorsed the activities of the United Nations Programme on Space Applications for 1994 as proposed by the Expert on Space Applications and as recommended by its Scientific and Technical Subcommittee at its thirtieth session. Subsequently, the General Assembly, by its resolution 48/39 of 10 December 1993, endorsed the Programme on Space Applications for 1994.

3. In response to resolution 48/39 and in accordance with the UNISPACE 82 recommendations, the Programme on Space Applications included, as one of its 1994 activities, the organization of a training course on remote sensing education for educators.

4. The Fourth United Nations Training Course on Remote Sensing Education for Educators was organized in cooperation with the Government of Sweden through the Swedish Board for Investment and Technical Support (BITS) and was hosted by the Department of Physical Geography, Stockholm University, and the Swedish Space Corporation (SSC Satellitbild), Kiruna, for the benefit of developing countries. The course was held at Stockholm and Kiruna from 2 May to 10 June 1994.

5. The main objectives of the training course were to provide participants with educational and practical information on current and future remote sensing systems, including the acquisition, processing, interpretation, application and archiving of the data generated by such systems, to demonstrate different satellite remote sensing methods; to expose the participants to various aspects of the application of satellite data, including data and materials from the participants' own countries, in project planning and management; as well as to equip them with the ability to introduce elements of the technology and its applications, as appropriate, into the educational curricula of their universities and institutes.

6. The present report covers the background, objectives and organization of the training course, as well as a general summary and an evaluation of the course. The report has been prepared for the Committee on the Peaceful Uses of Outer Space and its Scientific and Technical Subcommittee. The participants will report to the appropriate authorities, universities and research institutes in their own countries.

7. The participants expressed their appreciation to the United Nations and the Government of Sweden for organizing and hosting the course and for their financial assistance, as well as for the gifts of images.

B. Organization of the training course

8. The course was opened in Stockholm by Professor K. Fredga, Director-General of the Swedish National Space Board, on behalf of the Government of Sweden, Mr. S. Pettersson, Director of the Department of International Training Programmes on behalf of BITS, Professor L. Wastenson, on behalf of the President of Stockholm University, Mr. R. Bergstrom, Project Administrator, on behalf of SSC Satellitbild and Dr. A. A. Abiodun, the Expert on Space Applications from the United Nations Office for Outer Space Affairs.

9. Participating in the course were 27 educators from Bangladesh, Colombia, Costa Rica, Guyana, Jamaica, Jordan, Kenya, Morocco, Namibia, Nepal, Nigeria, Pakistan, Palestine, Panama, Peru, Sri Lanka, Swaziland, Tunisia, Uganda, United Republic of Tanzania, Uruguay, Viet Nam, Yemen and Zimbabwe.

10. Funds allocated by the United Nations were used to defray the costs of international air travel for 11 participants. The Government of Sweden provided room and board, local transportation and a daily subsistence allowance for all the participants, as well as international travel expenses for 16 participants.

11. The programme of the course (contained in annex I of this report) was designed jointly by the United Nations Office for Outer Space Affairs, Stockholm University and SSC Satellitbild. The presentations at the course provided participants with a basic understanding of the development and use of remote sensing technology in natural-resource management and environmental assessment. They were also aimed at equipping participants with the ability to introduce elements of the technology, as appropriate, into the educational curricula of their universities and educational institutions. Other topics covered during the six-week training course were an overview of remote sensing applications with emphasis on case-studies in which data and satellite imagery of the countries of participants were used, principles of visual and digital image analysis, use of Geographic Information Systems (GIS) in different fields of applications and remote sensing.

12. Through illustrated presentations, participants shared their experiences with one another in case-studies and projects/programmes in which they were involved (see annex II of this report).

13. Some of the presentations clearly demonstrated that the use of remote sensing techniques had an impact on decision- and policy-making. Other presentations in which participants used data and satellite imagery from their own countries provided an overview of remote sensing techniques and use of GIS in different fields of applications.

14. Numerous practical exercises and field trips at the Abisco Scientific Research Station (100 km north of Kiruna) were organized in order to provide the participants with the opportunity for practical training in the visual interpretation of remote sensing data. The course was supplemented with visits to SSC Satellitbild facilities and laboratories at Kiruna and the European Space Agency (ESA) Salmijärvi Ground Station and at the ESRANGE satellite station of ESA.

I. SUMMARY OF THE COURSE

A. Remote sensing and global change

15. Advances in measurement technology, particularly satellite-borne remote sensing, allow global monitoring of the environment. New generations of computers have increased the capability to synthesize data sets and to develop increasingly comprehensive numerical models. These tools, coupled with the growing understanding of the components of the Earth system - the atmosphere, oceans, soil and solid Earth - and the physical, chemical and biological processes that link them, permit an integrated and interdisciplinary approach to Earth-system studies.

16. Traditionally, monitoring environmental changes is done either by ground surveys or aerial photo-interpretation and these changes are normally detected through a manual comparison of a single-data analysis. For large areas, however, both ground surveys and aerial photo-interpretation methods are impractical due to the large amount of data to be collected and processed, and to improper data handling. Remote sensing, with its large area coverage and short repetitive cycle, offers a new and effective alternative. In addition, the digital nature of the data collected makes computer processing possible, which is an advantage in the handling of a large volume of data.

17. Throughout the years, various methods for detecting environmental changes using remote sensing techniques have been developed and successfully tested. Space technology has become operational and is being used widely in many countries for resource management and environmental applications. Various case-studies and projects have shown that remote sensing contributes significantly to economic and social development and to an understanding of global change. Presently, all parts of the world are being monitored by Earth observation systems. The data obtained by such sensor systems may represent the only reliable information on a given country; an indispensable element, in developing environmental models and data management systems for the country in question. These models and systems are crucial to human understanding and safeguarding of the environment as well as to ensuring a more effective management of natural resources at both national and global levels.

18. The latest contribution to operational Earth observation from space is the microwave sensor system, which can function in the dark and can penetrate rain and clouds, thus enhancing the possibilities of obtaining needed information from cloud-covered areas. ERS-1 and -2 of ESA, JERS-1 of Japan and the forthcoming RADARSAT of Canada exemplify the space systems that are providing this type of information to the global community and will continue to provide it in the years to come.

19. The availability of space-acquired data of the Earth will assist the international community to gain a better understanding of how to safeguard the global environment as well as to ensure a more efficient management and productive harnessing of the natural resources of the planet. Major global programmes such as the International Geosphere-Biosphere Programme (IGBP) and Mission to Planet Earth will contribute to the understanding of global change. However, a prerequisite for the effective participation of all countries in international programmes, as well as in national and regional projects is an adequate and long-term commitment to and investment in the development of skills and knowledge in the discipline at the local level.

B. Remote sensing applications: Limitations and potential in developing countries

20. The need for and applications of remote sensing in the developing countries have been explored by many countries; however, its utilization is constrained by several factors. These include lack of capital; limited access and non-availability of remote sensing data; lack of trained qualified manpower; inappropriate and incomplete technology transfer; and inadequate planning by decision makers, planners and technical personnel.

21. The above problems are diverse in nature and vary from country to country. Thus the strategy to solve these problems also varies from country to country. However, these strategies have certain factors in common. These include inter alia:

(a) Highlighting the importance of the technology in national planning in order to ensure commitment by the Government; increase interactions between decision makers, planners and technical personnel, an exchange of information and expertise between countries, at the regional and international levels;

(b) Introduction of methods so that the use of remote sensing could (i) have an immediate impact; (ii) become operational rapidly; and (iii) require limited investment.

22. In order to begin to respond to these problems, it is necessary to develop skills and knowledge at the local level. An appropriate educational programme for educators will contribute to the development of indigenous capability, to the quality and quantity of input of national specialists in the development of their countries and in the management of their resources and environment.

23. The over-emphasis on computer-based handling of satellite data and the concentration of all resources and competence at single, national centres are likely to hinder and seriously delay the vast amount of

development work that is necessary to find suitable methods of applying a practical application of the technology. Similarly, the belief that the analysis of satellite data is a highly sophisticated technology which requires large and advanced computer resources will hamper the transfer of satellite data from laboratory to users at local levels, as well as the application of the information derived therefrom.

24. In the future, satellite data will be distributed in formats and on media that can be read and analysed by low-cost personal computers at regional and local levels, i.e. where most of the practical work and field inventories are made. At present, however, satellite data can easily be distributed as images for use at those levels, as it is possible to fulfil many of the requirements listed above if much of the same technique and instrumentation that are used for studies of aerial photographs are applied in the analysis of satellite images.

25. As aerial photography has been used in all developing countries for a long time for topographic mapping, land-use and soil conservation planning etc., there exists a variety of local competence in many countries. Most authorities and institutions working with aerial photographs are usually well-equipped with viewing equipment, such as stereoscopes and stereo plotters, which can also be used for the study of satellite images. If necessary, satellite data vendors can also tailor images to fulfil the demands of the client but leave the image interpretation itself to the real experts, the end-users.

26. The specific training needed for satellite-image analysis is mainly for local scientists, with a basic degree in their field of expertise in order to familiarize them with the new types of image the satellite systems provide. A crucial factor is the fact that local scientists are familiar with the topography, geology, land-use patterns and cultivation practices in their project area. All these factors are very important for the analysis of satellite images.

27. Past experience of applied satellite-remote sensing in developing countries has confirmed that visual interpretation of standard or enhanced image products is the most rewarding path to follow if the intention is to obtain appropriate results by rapidly utilizing the local expertise involved in practical project work.

C. Remote sensing training strategy in developing countries

28. Up-to-date, reliable and readily renewable information on land, in the broadest sense, is a prerequisite for the effective planning and administration of natural and human resources. There is an increasing awareness in developing countries of the important role that remote sensing techniques in the form of aerial photography and satellite imagery can play in this context. The data that can be extracted from remote sensing imagery, using a wide range of techniques of different levels of sophistication, are multisectoral and can be used for land-use planning and environmental protection, forestry and agriculture, for geological- and mineral-exploration purposes, for water-resources inventories, for communication, mapping and environmental monitoring.

29. The need for remote sensing technology is well understood and demands for its further implementation are growing. In most countries, considerable investment has been made in aerial photography during the past few decades and it is anticipated that full coverage by satellite imagery of a national territory has been or will soon be achieved. The major constraints on a wider and more efficient use of remote sensing techniques are the (a) lack of knowledge of the realistic potential of these techniques at the decision-making level; (b) limited number of trained specialists; and (c) lack of trained technicians at the local level.

30. There is a great need for a three-level training programme aimed at the following groups:

(a) Managers: heads of agencies, heads of departments and decision makers, which should include also participants from non-technical groups;

(b) Specialists: those who have already gained experience in working with remote sensing techniques and who have a basic knowledge of the scientific background of this technology;

(c) Technicians: with emphasis on local-level staff. This group may have a limited knowledge of remote sensing but can be expected to become the most active users of the technique.

31. Three packages could be envisaged, tailored to meet the needs of the three target groups. It will be necessary to prepare exhibition materials, manuals and compendiums, and audio-visual materials.

32. The course for managers should include an overview of the remote sensing concept and of remote sensing techniques as well as a presentation of the current applications of these techniques and their future potential. Concrete examples of the application of these techniques and their cost-benefit in the country concerned should be encouraged. An exhibition would be a valuable tool and offer possibilities for audio-video presentations.

33. The course for specialists should be aimed at broadening and deepening their knowledge of remote sensing beyond the current national level of technology towards more efficient image-analysis systems. There should be a balance between theory and practical exercises. As it is hoped that several of the specialists can teach in the training courses for technicians, emphasis should be placed on teaching methods. The course should include, inter alia, the remote sensing concept, aerial photography methods, basic photogrammetry, photo-interpretation, satellite imagery and image analysis, image interpretation and mapping from satellite imagery, presentation of the results of photo-interpretation and image analysis, comparisons of classical and satellite methods, and the economics of remote sensing.

34. The course for technicians should be a simplified variant of the one for specialists customized to meet practical requirements.

35. The three-level training programme could be organized as follows:

Managers: One- or two-day seminar given once a year.

Specialists: Short- or long-term courses. A certain amount of customization will be carried out to meet specific interests.

Technicians: Short- or long-term courses with staff mainly recruited from the specialist group.

In addition to these training programmes, on-the-job training should also be encouraged.

D. Remote sensing satellite systems

1. Landsat system

36. Data and images from the Landsat system have been available since 1972. The result has been that most areas of the world are now well-covered, with several images taken over the same areas at different times of year. This repeated or multitemporal coverage is one of the important advantages of the system as it permits early detection and monitoring of potential environmental hazards as well as season-dependent changes in farming, natural vegetation etc.

37. Another characteristic of great importance, compared to conventional aerial photography, is the multispectral capabilities of the sensor systems onboard the satellite. Instead of being limited to acquiring images of the scene in the visible and near infrared region of the electromagnetic (EM) spectrum, as with

camera and film, the Landsat multispectral system records images from several bands of the visual, near and thermal infrared regions. Analysis of an image obtained in a specific part of the spectrum, or combinations from two or more bands (images), can help to differentiate between terrain features and details, which otherwise would be difficult to separate. The wavelength band intervals for two of the Landsat sensor systems, the Multi-Spectral Scanner (MSS) and Thematic Mapper (TM), are indicated in the table below. The spatial resolution of the images obtained by the MSS sensor is 80 metres, while the resolution of the TM sensor is 30 metres.

Wavebands for Landsat and SPOT detectors
(μm)

	Landsat		SPOT	
Band number	MSS	TM	SX	P
1	0.5-0.6	0.45-0.52	0.50-0.59	0.51-0.73
2	0.6-0.7	0.52-0.60	0.62-0.68	
3	0.7-0.8	0.63-0.69	0.79-0.89	
4	0.8-1.1	0.76-0.90		
5		1.55-1.75		
6		10.4-12.5		
7		2.08-2.55		

38. Overview images, also called "quick-looks", can be ordered as small-scale paper prints from Landsat images to check cloud cover and to identify geographical location. Quick-looks are MSS products but cover the same areas as the simultaneously obtained TM images.

39. Full-resolution images can be ordered as paper or film print in black-and-white or in colour. The spectral bands can be chosen for specific purposes and can be combined to form a colour composite. Due to the increased number of pixels in the corresponding TM images, TM photography products are processed only in quarter-image scenes. The most common scale of the MSS film originals is 1:1,000,000, while for TM film products it is 1:500,000 (quarter scene).

40. MSS and TM data in digital form are delivered as full scenes with all spectral bands or a single spectral band. TM data can also be ordered covering only a quarter of the full MSS scene. Data are delivered either in raw form or corrected for radiometric variations and geometric distortions.

2. SPOT system

41. The SPOT satellite system is in many aspects similar to the Landsat system. It has similar multispectral and multitemporal characteristics as well as the potential of large-area coverage.

42. A notable difference is the capability of SPOT to provide images of the same area obtained from consecutive orbits. While Landsat only gives a flat representation of the land surface directly below the satellite, SPOT can be programmed to view the same area during its next three orbits. This allows the construction of a quasi-stereoscopic image that can be utilized for topographic mapping. Recent studies indicate that it is possible to produce topographic ortho-photo maps to the scale of 1:50,000 and larger, with contour intervals of 20 metres, by direct measurements based on digital-image data.

43. Images of the Earth are obtained by SPOT with a resolution of 20 metres in its multispectral mode and 10 metres in its panchromatic mode. However, the higher resolution of the SPOT system leads to an increase of up to nine times in the number of picture elements to be handled per unit. To be able to handle all these data, the size of the scene has been reduced to approximately one tenth of that of the Landsat MSS scene, or 3,600 km^2. More SPOT images are required to cover the same area as that covered by Landsat and the cost is therefore higher.

Standard SPOT products

44. Standard SPOT products comprise entire scenes or parts of scenes. A scene corresponds to a terrestrial area with a length of 60-80 km and a width of 60 km, depending on whether the image is obtained vertically or looking to the side. The scenes are identified on a predetermined grid on the Earth's surface and with latitude and longitude.

45. Standard products can be ordered at three levels of processing:

Level 1A. The data are basically raw (unprocessed). Information from the detectors has been processed to normalize each spectral band. Coefficients for calibration between bands and absolute values are specified. No geometrical correction is included. The instrument's viewing angle is specified. This level of processing is particularly suitable for basic radiometric studies and stereo projections;

Level 1B. The data have been corrected for systematic errors with regard to radiometry and geometry, and to account for the Earth's rotation and curvature and angle of registration;

Level 2. The data are geometrically precision-corrected. In addition to the radiometric correction in level 1B, the image has been corrected on the basis of maps or ground-control points and presented in an optional cartographic projection. Processing is done without a digital terrain model. This means that for areas with a relatively low relief and almost vertical view angles, a positional accuracy of 10 metres can be achieved for multispectral images and 5 metres for panchromatic images.

Special SPOT products

46. In addition to the above-mentioned standard products, a number of special products are either currently available or will be in the near future, including:

Merged multispectral and panchromatic data
Scene-shifted image along the satellite track
Mosaic from two adjacent scenes along the satellite track
Mosaic from four adjacent scenes
Quarter-scene film products
Large format film products
Stereoscopic pairs
Digital terrain models extracted from SPOT stereoscopic pairs
"Level 3" geometric geocoding using ground-control points and digital terrain models to remove local distortions.

47. SPOT images are particularly advantageous in erosion studies due to its superior geometric resolution and its stereo capability. SPOT multispectral images give information on land use, land cover and soil type, while the panchromatic images give terrain details. SPOT stereo pairs give topographic information. All this is essential for the assessment of soil-erosion status and soil erodability.

E. Visual interpretation of satellite images

48. Photographic images are the cheapest and most readily available remote sensing data. They may be acquired directly by cameras mounted on aircraft or satellites, or produced from digital image data. Images in this form, either black and white or colour, are available for all parts of the electromagnetic spectrum accessible to remote sensing systems.

49. At the time of the introduction of the Landsat system the expectations for practical applications were quite high, particularly in the developing countries. The monitoring of environmental changes and inventories of natural resources in areas lacking the conventional monitoring systems of the industrialized world, i.e. ground-based and aircraft remote sensing systems, were among the many important tasks to be accomplished in order to cope with increased demands on land.

50. The low resolution of the first image products and the vast amounts of data, however, favoured the development of computer-based data analysis systems. When such systems were first introduced in the developing countries, their use was based on overseas technical and human resources, while local knowledge and competence concerning the land and its resources were usually unused. The many studies to date have been conducted by foreign experts without a concomitant education of local experts of the principles on which the technology is based. Once the foreign experts left, the training experience acquired had a limited influence on new practical applications and on the development process. There has also been an overestimation of the use of computer-assisted remote sensing techniques, and the lack of applicable results has to some extent led to a disappointment among local experts.

51. In many cases, visual interpretation of satellite images, with a knowledge of the physical process that led to them, may prove to be a preferable alternative to numerical analyses, especially in developing countries. The involvement of local expertise as well as the application of the results will be easier to achieve. The introduction of the SPOT satellite system, with a much higher resolution and the possibilities of stereo viewing, will further this approach.

52. One advantage of visual interpretation is that the same equipment can be used for conventional interpretation and mapping from aerial photographs. All developing countries have such facilities and, more importantly, competent staff with a good knowledge of local conditions. By contrast, many of the computer-based studies rely upon foreign equipment and foreign experts.

53. A practical application of the visual interpretation of satellite images has evolved in the developing countries because of their urgent need for rapid access to actual data for assessment of land and water resources. In most cases visual interpretation of Landsat and SPOT imagery has been based on either black or white images of the various spectral bands or on false colour composites (FCC). Bitemporal and multitemporal analyses are often made in order to improve the classification of the various landscape elements or to monitor the annual or seasonal changes.

F. Land-use planning and environmental monitoring

54. Space-borne remote sensing data are a very important source for land-use planning and environmental monitoring. These data are suitable for applications on the local or regional level and also for national or global investigations. Of special interest for monitoring applications is the possibility of collecting information over large areas in a short time and of repeating the data collection at regular intervals.

55. Most of the applications in this area often have in common the need to map current conditions, natural or produced by man, to use this information to manage properly the natural resources of a country or region

and to monitor the environment to avoid or reduce undesirable effects on the environment and on a country's resources.

56. Image interpretation as well as digital image processing techniques are suitable tools for the evaluation of remote sensing data for land-use planning and environmental monitoring. The purpose and goals of a specific investigation or application problem and the available resources determine how these evaluation techniques can be used. The proper selection of appropriate data types and dates for image collection are crucial for the success of individual applications.

57. For land-use planning, high resolution space-borne data from SPOT or the Landsat TM for example, provide an excellent data source that often gives more recent information on local or regional conditions than existing maps. Conversely, weather satellite data and routinely derived products, such as vegetation index maps over Africa for a 10-day or one-month period, can be suitable for national or continental monitoring of the environment.

1. Land use and vegetation mapping

58. Land use, land cover or vegetation maps provide important information on the current extent of different land uses or land covers. With remote sensing data, major vegetation types and other land cover, such as bare soils, water or built-up areas, can be identified. In fact, it is possible to deduce from the land cover and its spatial distribution specific land uses, for example, agricultural or residential areas. Other land uses, for example, a national park, cannot be determined with remote sensing data without additional information.

59. For many applications, land-cover or land-use maps do not require the same level of detail as used in agricultural or forest applications. Therefore, it is often easier to produce a useful land-cover or land-use map of a given area and it often requires less knowledge of local conditions than a detailed map of agricultural crops. Standard image interpretation techniques are very efficient for identification and mapping of all major land use classes. Interpretation experience from areas with similar natural conditions can reduce to a minimum the need for field checks.

60. In a typical colour infrared image, densely forested areas appear in different shades of dark red and brown, water in shades of blue, agricultural areas with lush green vegetation in shades of red and bare soils shading from blue to white. Field patterns can often be identified and provide indirect information on farm sizes and agricultural practices. Larger roads and railroads can often be identified, and the distribution and development of more densely populated settlements are also visible. Major topographical features, such as valleys, plains and mountain ranges, can be identified. Often it is possible to map and identify additional features and land properties, important for land-use planning, such as areas unsuitable for agriculture due to poor soils, excessive sloping or risk of flooding.

61. With high resolution, panchromatic SPOT data and derived maps can be used in a wide variety of ways, for example, to map settlement types and areas, industrial areas (and sometimes even the type) and important natural conditions, such as rivers, valleys or the land-cover and land-use pattern. This information can then be used to decide in which areas further settlement activities would be acceptable, which areas should be reserved for agricultural use and which natural conditions would favour or limit development.

62. In rural surroundings, typical land-cover information might outline densely forested hilly areas or plateaux, plains or river valleys with agriculture or grasslands. Often typical patterns in the distribution of different agricultural usages emerge, indicating natural limitations or favoured areas. Often these data also outline drastic differences in the state of the vegetation cover, indicating differences in agricultural practices or pressures on the land, which often result in severe degradation of the natural conditions due to

over-exploitation. This information can be used to decide on necessary or possible changes in land use and to reduce negative effects of current land use.

63. The greatest advantage gained by using satellite images instead of conventional air-photo mosaics for land-systems mapping is that the same colours prevail over large areas, representing the same type of terrain or vegetation. The colours are good indicators of soil type and drainage conditions due to differences in moisture content and vegetation. SPOT satellite images have subsequently been tested for land systems mapping of the same area, and the stereo option has further enhanced the interpretation of the land systems and the subdivision of the systems into land facets.

2. Monitoring of change

64. Land use, vegetation cover and other natural conditions are not static and change with the seasons or over long periods. These changes are of interest, for example, in the follow-up of planning decisions or in verifying the efficiency of protection measures.

65. In monitoring changes, it is essential that the differences observed between two images or data sets are really due to a type of change on the ground that should be monitored and are not produced by other effects, such as data-collection conditions. Two images of the same location, one taken during the dry season, the other near the end of the rainy season, for example, typically differ drastically in their appearance, mainly due to differences in vegetation development and the distribution of agricultural crops. For the mapping of crop types or the monitoring of the seasonal development of vegetation, this type of information could be of great relevance. Used for monitoring the efficiency of erosion-control measures or the extent of erosion, it could result in very serious misinterpretation.

66. The use of sequences of remote sensing data to monitor urban development or large-scale clearcutting of forests is comparatively easy and reliable. The differences between two images in these areas are typically very large and have characteristic patterns, of roads for example, that facilitate the separation of induced from natural changes. Problems occur if the affected areas are comparatively small or the change is only gradual.

67. The situation is much more critical if only small colour changes between the images are used to obtain information on changes. Minor differences in the weather situation during data collection, slight delays in vegetation development and the side effects of standard processing routines can result in colour differences between two scenes even if they are taken about the same time in different years. Therefore, results based mainly on colour changes at the same time of day but on different dates, without other clear indications in the image, should be checked very carefully to avoid misinterpretation.

3. Water-resources development and environmental monitoring

68. Remote sensing data can be used in many ways for the development and efficient use of available water resources, which are crucial in many countries. Specific water resources, groundwater for example, can often only be indirectly mapped by remote sensing. But remote sensing data provide many clues for the assessment of water resources, even if direct measurements are only possible in a few cases. In most of the developing countries, shortage of drinking water due to recurring drought and contamination of fresh-water aquifers by pesticides and industrial wastes are the common problems in water-resource management. In order to combat this problem of drinking water, particularly in drought-prone areas, remote sensing has been very effectively used in several developing countries for identifying aquifers to enable ground-water exploitation.

69. Drainage systems, catchment areas and the extent of water in major rivers and lakes can be determined from satellite data. Interpretation of types of vegetation and soil provides clues to the water available to

plants, infiltration of water into the ground and expected surface run-off. In combination with weather data, this allows at least an estimate of areas with sufficient availability of water for use for different types of agriculture or grasslands. Furthermore, this information can be used to estimate the expected surface run-off and its seasonal variation within catchment areas to provide essential information for the planning of reservoirs and dams for irrigation and the production of electricity.

70. Satellite data can also be used to judge the extent and possible rate of soil erosion. Methods for a more quantitative determination of surface run-off, erosion and sedimentation rates, using remote sensing data, are under development. Attempts within the African Real Time Environmental Management Information System (ARTEMIS) project of the Food and Agriculture Organization of the United Nations (FAO) to estimate precipitation in Africa based on data obtained by polar-orbiting satellites should provide interesting information on a 10-day and one-month basis. Within this project, vegetation index maps for Africa with the same time intervals are also produced.

71. High resolution data from SPOT or the Landsat TM can also be used to map erosion-affected or erosion-prone areas. Typically, this requires familiarity with general regional conditions and erosion processes. Additional information might be useful to differentiate various types of erosion-affected areas.

G. Visits to satellite stations

1. SSC/ESRANGE Satellite Station

72. SSC satellite operations facility and sounding rocket range near Kiruna, known as ESRANGE, in the far north of Sweden, is Europe's largest civilian space facility. The geographical position of the facility offers several unique advantages. For satellite control and operations, the location north of the arctic circle gives 2-3 times more frequent access to polar-orbiting satellites than is possible with stations at lower latitudes. For sounding rockets, an impact area of approximately 120 x 75 km is available for land recovery. This facilitates payload design and allows experiments to be recovered within an hour from launch. ESRANGE takes an essential part in many remote sensing, scientific and communications satellite projects. Data reception services and tracking, telemetry and command (TT&C) operations have already been provided or contracted for a number of satellites - EXOS C-D, FREJA, LANDSAT 2-5, MOS 1-2, SPOT 1-3, TELE-X, VIKING - and others are to follow. The most important customers are Centre National d'Etudes Spatiales (CNES), ESA and the National Space Development Agency (NASDA), Japan.

73. The satellite data receiving station has several independent antennae and processing systems to handle data from remote sensing and scientific satellites. Data is delivered in real time or processed for storage on standard media.

74. The satellite control station is of universal design and performs TT&C operations on orbiting satellites. ESRANGE operates and monitors satellites on behalf of customers or offers the use of the station in a transparent mode where a remote customer is connected to the station for real time access to a satellite.

75. Sounding rockets launched and balloons flown at ESRANGE are used for experiments in microgravity and studies relating to high latitude space physics, astronomy, the chemistry of the upper atmosphere and the ozone problem in the northern hemisphere. Balloon payloads up to 500 kg can be flown from ESRANGE to altitudes above 40 km. The experimental period can be 20 hours or more. Recovery is carried out within the land area of northern Scandinavia and Finland.

2. ESA/Salmijärvi Satellite Station

76. Close to ESRANGE, ESA established in 1991 the Salmijärvi Satellite Station as the main station for the ERS-1 satellite. The operation and maintenance of the station is contracted to SSC ESRANGE. Connected by satellite links to users all over the world, the station processes and disseminates acquired radar sensor data in close to real time.

77. Launched in July 1991, ERS-1 is a low-orbit Earth observation satellite with several microwave sensors onboard. The primary mission of ERS-1 is to increase the understanding of ocean processes, to monitor the polar regions and to contribute to the World Climatology Research Programme. However, land-oriented applications will increase as the international research community gains access to the data. The primary instrument on board ERS-1 is the Active Microwave Instrument (AMI), which can provide high-resolution images (C-band), wind speed through ocean-wave spectra analyses and the length and direction of ocean waves. Operating in the imaging mode, AMI covers a swath of 80-100 km, with an initially assessed resolution of 27 metres in range and 29 metres in azimuth.

78. Since its launch in July 1991, the ERS-1 satellite has acquired over 400,000 radar scenes. Of these, some 10,000-15,000 have been processed. In environmental applications, the all-weather advantages of the synthetic aperture radar (SAR) of ERS-1 for tropical, high-rainfall and equatorial regions have been proven.

79. ERS-1 SAR data are particularly useful for coverage of a large area. For studying non-renewable resources, the spectral wealth of SPOT data complement the ERS-1 data as regards texture and the interpretation of morphology, particularly in areas of low relief. However, certain phenomena continue to pose interpretation problems.

80. For renewable resources, ERS-1 data combined with optical data provide more information than was anticipated. In agriculture, projects are in progress to incorporate ERS-1 data into a number of programmes. The results obtained so far demonstrate the usefulness and complementarity of radar data for discriminating and monitoring different crops. In the same way, ERS-1 data provide coverage of certain areas of tropical forest in the Amazon region, making it possible to locate and monitor deforestation.

II. TRAINING COURSE EVALUATION

81. At the conclusion of the course, the participants were asked to complete a questionnaire regarding various aspects of the content and organization of the course, including the time allotted to the topics and practical exercises as well as to the relevance of the course content to their day-to-day activities. The participants expressed the view that a general evaluation of the course did not permit evaluation in terms of its specific aims and objectives, for example, the Kiruna Obisko exercises with its practical and theoretical components.

82. Referring to the composition of the programme of the course, depending on their experience and field expertise, the participants noted that the overall level of the programme was adequate and the majority considered that the theoretical and practical training corresponded, to a sufficient extent, to their professional needs. The participants stressed that topics such as digital image processing and analysis, GIS and application of geology would require more time for training and therefore more time should be allotted for these topics, while the time allotted for such topics as visual interpretation, poster production and participants' presentations could be shortened. They also were of the opinion that the hours of instruction should be reduced in order to concentrate more on studying.

83. Following the evaluation exercise, general discussion took place on the problems of remote sensing education in developing countries. The participants made a number of observations. They stressed the necessity of the following:

(a) Developing infrastructural facilities and manpower capabilities in each country in order to utilize remote sensing technology in various fields;

(b) Strengthening the existing mechanism of information exchange by organizing more conferences, publishing a newsletter or other documentation or establishing networking arrangements;

(c) Exchanging information on education and training capabilities and expertise through workshops, on-the-job training etc.;

(d) Undertaking joint research projects and field applications of mutual interest to promote appropriate interdisciplinary studies on a regional basis among the participants and organizers of the course;

(e) Strengthening international collaboration between developed, developing and international agencies. There is a need for cooperative ventures which will provide access to data and interpretation analysis facilities at a reasonable cost.

84. The participants were of the view that implementing the above observations with the effective and efficient use of satellite-remote sensing technology would help to improve the quality of life, and therefore, extensive use of this technology is encouraged at national, regional and global levels.

85. All participants expressed the opinion that the general organization and planning of the presentations were of high quality. All the participants were of the view that the level and conduct of the course were appropriate for the specific needs of their educational and academic work and that the course was very well organized and administered. They also expressed their appreciation to the Government of Sweden and to the United Nations for having organized the course.

Annex I

PROGRAMME OF THE COURSE

I. INTRODUCTION

Department of Physical Geography, Stockholm University

Date	Subject	Speaker
Monday 2 May	Opening ceremony Welcome addresses	
	Introductory lectures:	
	Capacity development at the local level	A. A. Abiodun
	Remote sensing and global change	N. Swanberg
	Remote sensing in Sweden	L. Wastenson
	Management of natural resources and the environment - the role of remote sensing	M. Byström
	Presentation of the Department of Physical Geography - education and research	W. Karlén C. Christiansson B. Lundén

II. FUNDAMENTAL PRINCIPLES

Tuesday 3 May	Electromagnetic radiation, the reflective properties of the earth and elementary optics	J. Kleman P. Syrén
Wednesday 4 May	Electronic imaging Electronic imaging (continued)	F. Quiel F. Quiel
Thursday 5 May	Modern cartography in thematic mapping Image geometry and map projections	M. Buchroithner M. Buchroithner
Friday 6 May	Earth resources and environmental satellites Image interpretation - theory	M. Buchroithner G. Alm
Monday 9 May	The new generation of environmental satellite - the case of ERS-1	J. Lichtenegger

III. IMAGE INTERPRETATION

Department of Physical Geography, Stockholm University

Monday 9 May	Remote sensing for land-use planning and environmental monitoring	F. Quiel
Tuesday 10 May	Remote sensing for geological studies	B. Lundén
	Introduction to visual interpretation and in-service training in remote sensing in developing countries	R. A. Larsson

Wednesday 11 May	Case-studies:	
	<u>Africa</u>	
	Land and water development in Ethiopia	R. A. Larsson
	Land use mapping in the United Republic of Tanzania	L. Strómqvist
	<u>Asia</u>	
	Environmental impact assessment of the closure of a river arm in Bangladesh	R. A. Larsson
	Environmental impact assessment of hydropower development in the Lao Peoples' Democratic Republic	L. Strómqvist
	<u>Latin America</u>	
	Forestry in Ecuador	R. A. Larsson
	Geological applications from Central America	R. Lilljequist
	<u>General Case-Study</u>	
	Land degradation and soils in Lesotho	B. Lundén

IV. REMOTE SENSING EDUCATION AND PROJECT MANAGEMENT

Thursday 12 May	Remote sensing project management Poster production	D. Asvärn W. Arnberg
Friday 13 May	Poster production (continued) Presentation of posters	W. Arnberg W. Arnberg

III. IMAGE INTERPRETATION (continued)

Monday 16 May	Case-studies for Africa, Asia and Latin America
Tuesday 17 May	Case-studies for Africa, Asia and Latin America (continued)

V. DIGITAL IMAGE PROCESSING AND ANALYSIS/GIS

Department of Physical Geography, Stockholm University

Wednesday 18 May	Digital analysis (theory) Computer enhancement (theory) AVHRR reception and handling	G. Alm G. Alm O. Rud
Thursday 19 May	Geographical Information Systems (GIS) (theory)	F. Quiel

Friday 20 May	Introduction to exercises in digital techniques	G. Alm W. Arnberg B. Lundén K. Wester O. Westerberg
	Computer-aided analysis, GIS application and CD-ROM data capture. Digital techniques	G. Alm W. Arnberg B. Lundén M-L. Nordberg K. Wester O. Westerberg
Monday 23 May	Departure for Gävle; visit to Swedesurvey Presentation of Swedesurvey and the National Land Survey of Sweden Aerial photography - uses and products GPS in aerial photography GIS with regard to modern surveying and mapping techniques Scanning and automatic vectorization	L. Bäckström T. Djuvfeldt L. Bäckström T. Djuvfeldt
Tuesday 24 May	Digital techniques (continued)	G. Alm W. Arnberg B. Lundén M-L. Nordberg K. Wester O. Westerberg
Wednesday 25 May	Digital techniques (continued)	G. Alm W. Arnberg B. Lundén M-L. Nordberg K. Wester O. Westerberg
	Departure for Kiruna	

VI. REMOTE SENSING APPLICATIONS

SSC Satellitbild, Kiruna - Sweden

Wednesday 25 May	Arrived Kiruna Departure to field-work area (100 km NW of Kiruna) Scientific Research Station	R. Bergström

Thursday 26 May	Introduction to the Kiruna part of the course. Preparation for field-work exercise Field-work exercise. Excursion in the field-work area, demonstration of image material Presentation of Abisco Scientific Research Station and current research Exercises in landscape feature interpretation	R. Bergström A. Rydén A. Rydén A. Rydén
Friday 27 May	Field-work exercise: image interpretation Preparation for presentation of results of exercise	A. Rydén A. Rydén
Saturday 28 May	Presentation of results of the field-work exercise Departure for Kiruna	A. Rydén
Monday 30 May	Reception at SSC Satellitbild Data reception - processing Demonstration of the production facilities at SSC Satellitbild: Computer Hall: Archiving, catalogue up-dating, standard production Analysis Room: Precision Corrections, DTM extraction Interpretation Room: Terrain type classification Photo Laboratory: Equipment, quality management Samples of photo products Production facilities at National Land Survey Customer Service: Cat Eye Search System Visit to ESA Salmijärvi Satellite Station Demonstration of the Station Visit to ESRANGE Satellite Station Demonstration of the Station	L. Bjerkesjö L. Lundqvist K. Johansson K. A. Bergström M. Orrmalm S. Forslund M. Dahlberg J. Ek C. Kyllegard L. Alm
Tuesday 31 May	Satellite data archiving and processing, image production, satellite image maps, satellite ortophoto maps Digital map production at the National Land Survey Data acquisition, data correction, image production and costs. How to select the right type of data for a given task Presentation of case-studies from SSC and SSC Satellitbild Aktiebolag projects	T. Westin D. Klang T. Lundqvist L. M. Kartor M. Dahlberg A. Öskog R. Bergström J. Unga H. Rasch

Wednesday 1 June	Practical applications: visual interpretation exercises in groups using satellite imagery in (simulated) projects from the participants' home countries	M. Byström
	Demonstration of an actual Vegetation Mapping project	R. Bergström M. Chakanga
Thursday 2 June	Practical applications (continued)	M. Byström
Friday 3 June	Practical applications (continued) Preparations for the presentation of the results of the visual interpretation project work	M. Byström
Saturday 4 June	Presentation of the results of the visual interpretation project work	M. Byström

VII. NEEDS OF THE USER

Monday 6 June	Trends in remote sensing, contributions to research and applications in the third world Discussion between participants and trainers	W. Bie
	Departure for Stockholm	

IV. REMOTE SENSING EDUCATION AND PROJECT MANAGEMENT (continued)

Department of Physical Geography, Stockholm University

Tuesday 7 June	Arrival Stockholm	
	Lectures and work in groups on remote sensing education	W. Arnberg
Wednesday 8 June	Lectures and work in groups on remote sensing education (continued) Exercises in map-reading, orientation and the use of Global Positioning System	W. Arnberg
Thursday 9 June	Lectures and work in groups on remote sensing education	W. Arnberg
	Presentation of results	W. Arnberg B. Lundén
	Preparation for course evaluation Practical aspects of setting up a remote sensing laboratory	

VIII. SUMMARY AND EVALUATION

Friday 10 June	Swedish foreign aid Course evaluation	M. Gustavsson M. Gustavsson W. Arnberg R. Bergström R. K. Larsson B. Lundén F. Quiel L. Wastenson

Annex II

PRESENTATION BY PARTICIPANTS

6 May-9 June 1994
Stockholm - Kiruna

AFRICA

	Title	Name
1.	Participatory remote sensing for sustainable forest development	N. Ochanda, (Kenya)
2.	Remote sensing and agrometeorological models	M. Lahlou (Morocco)
3.	Vegetation mapping in northern Namibia	M. Chakanga (Namibia)
4.	Forestry research in Nigeria: Case-study of social and economic factors affecting farm forestry	O. Kadeba (Nigeria)
5.	A typical case of the status of remote sensing education in Nigeria	A. Okhimamhe (Nigeria)
6.	Research activities in the geography, environmental science and the planning department at the University of Swaziland. Potential uses of remote sensing	P. Fakudze (Swaziland)
7.	Application of remote sensing on environmental monitoring of small-scale gold mining in the United Republic of Tanzania	C. Kinabo (United Republic of Tanzania)
8.	Construction of an integrated GIS-based database for Karamoja	P. Buyinza (Uganda)
9.	Land use patterns in Harare	O. Namasasu (Zimbabwe)

6 May-9 June 1994
Stockholm - Kiruna

ASIA

1.	Application of remote sensing technology in Bangladesh	Y. Rana (Bangladesh)
2.	Remote sensing and geographic information systems in Jordan	H. Al-Kharabsheh (Jordan)

3.	Geophysical applications for engineering and groundwater studies	S. Pant (Nepal)
4.	Introduction to the existing Higher Educational system in the West Bank - Facts and needs An approach to Palestinian settlement policies - A settlement system integrated with planning and provision of community facilities, Ramallah District, West Bank	M. Abu-Helwa (Palestine)
5.	Exploration of Uranium by solid state nuclear track detectors	G. Akhtar (Pakistan)
6.	Centre for Integrated Mountain Research, Punjab University Concepts functioning strategy and achievements, the problems and effects of mass wasting in Northern Pakistan	K. Khan (Pakistan)
7.	Remote Sensing and GIS in Sri Lanka	A. Dhanapala T. Jayasingarn (Sri Lanka)
8.	Using aerial photographs for studying the mangrove area of Ho Chi Minh City	L. Thi Dinh (Viet Nam)
9.	A physical geography of Yemen	Al-Suneidar (Yemen)

6 May-9 June 1994
Stockholm - Kiruna

LATIN AMERICA AND THE CARIBBEAN

1.	Geographic and historic methods in national problems	J. Bernal-Hadad (Colombia)
2.	Presentation of Costa Rica Applications of GIS in Costa Rica	A. Rodriguez J. Saborio (Costa Rica)
3.	Exploitation, conservation and investment: Some environmental issues in Guyana	D. Bernard (Guyana)
4.	Remote sensing education of the College of Arts, Science and Technology (CAST), Kingston	N. Elvey (Jamaica)
5.	The use of remote sensing for natural resources inventory and geological structures mapping The Panama Canal	R. Bolanos (Panama)
6.	General characteristics of the geology of Peru - The use of remote sensing in exploration of the Andes Belt	C. Pinto E. (Peru)
7.	Remote sensing applications in Uruguayan coastal and shelf waters	G. Nagy B. (Uruguay)